PLUME FALLOUT DEPOSITS ON IO, THEIR COLOURS, AND RELATIONSHIPS WITH OTHER COEXISTING VOLCANIC FEATURES. V. Cataldo. Environmental Science Dept., Institute of Environmental and Natural Sciences, Lancaster University, Lancaster LA1 4YQ, U.K. (v.cataldo@lancaster.ac.uk)

In the Galileo era, most Ionian volcanic centers showing plume activity have revealed hot spot temperatures consistent with high-temperature silicate volcanism [1, 2]. At some of these locations, maximum temperatures ranging from 1400 K up to 2000 K (Pillan Patera) have also been inferred [3]. Due to the plume fallout, these volcanic centers are surrounded by deposits displaying a large variety of colours and patterns. In some cases, only dark circular deposits surround the vent region (Pillan Patera, Babbar Patera). The two Voyager spacecraft imaged dark, grey, and bright deposits. Bright deposits are commonly attributed to SO_2 condensation from plumes [4]. Galileo instruments have also imaged yellow, red, and dark red deposits which appeared just dark to Voyager instruments. On the contrary, other diffuse deposits, appearing dark to the Voyagers, have remained dark at all observed wavelengths to the Galileo imaging cameras. This is true both for “fresh” deposits, like the new deposits surrounding Pillan Patera, and the fan-shaped deposits extending from the Pele vent for 200 km (in radial extent), which appear unchanged since the Voyager era.

Today, this wide range of colours over the Ionian surface is still attributed to the existence of different sulphur allotropes [4]. Although such an explanation may be valid, we suggest that both dark and red diffuse deposits may consist of volcanic glass resulting either from plume-like activity or fountain-like activity. The likely existence of thin layers of condensed SO_2, with different thicknesses, deposited over the tiny volcanic particles may also contribute to make the colours different. In fact, some results from recent Galileo observations suggest that colouration is not diagnostic of sulphur or sulphur-compound frost: red and gray diffuse deposits have been imaged near the Pele volcanic vent at a distance where temperatures are too high for any gas condensation to occur [5]. Galileo observations have also confirmed that Pele’s fallout deposits are deficient in SO_2 frost [6]. Although debatable, the likely existence of particles landing still warm on the surface at Pele has already been proposed [5]. Red and dark red diffuse deposits have also been imaged near some volcanic centers at which fountain-like activities have been inferred [7]. With regard to the dark deposits, the new ring-shaped dark deposits at Pillan Patera have recently been associated with the “dark mantle” lunar deposits of Wilson and Head [8] and Wilhelms [9]. Similar deposits also surround the Babbar Patera volcanic center, known since the Voyager era, at which no activity has been observed.

Magmatic droplets, submillimetric to millimetric in size, entrained along with erupted gases within some plumes, are likely to constitute the observed dark deposits at the Pillan and Pele volcanic centers. The red diffuse deposits near the Pele vent are also suggested to have a similar composition. On the Moon, which has a similar gravity and atmosphere to Io, dark mantle deposits extended up to 200 km [8]. This value is similar to the radius of the dark deposits at Pillan Patera. Probably, large amounts of gas (up to 30 % by weight) and magma fragments, erupted at high speed (up to 1100 m/s) through a flared vent, would cause such deposits to extend up to 500 km from the vent. Furthermore, the gas-magma crustal interactions responsible for such eruptions would also enhance magma fragmentation similarly to phreatomagmatic events on Earth, and a larger number of the resulting magma fragments would be transported and deposited up to a large distance from the vent.

The likely interaction between rising magma and volatile deposits concentrated in the upper Ionian crust is probably responsible for the variety of volcanic styles observed. The eruption environment on Io is very similar to that on the Moon; for this reason, it is only in the near absence of gas in the Ionian magma that effusive flows can be produced on the surface [8]. As the gas amount becomes slightly larger, explosive volcanic activity is expected to occur, due to a near absence of an atmosphere and the lower gravity on the satellite. A low volatile content (less than 0.01 % by weight) is sufficient to produce ejection velocities resulting in the formation of a plume that covers an area as large as 42 km^2 [10]. In such cases, conditions for fountain-like activity can also develop. The existence of lava fountains on Io has been inferred from some ground-based observations [7]. A fountain-like event has been modeled by Davies [11] who has also suggested that pond-fed flows occur on Io. The distribution of the pyroclastic material over the surface depends on the material properties of the magma and the vent geometry, but primarily on the magma volatile content [8, 12]. However, the optical depth of the lava fountain and the temperature of the accumulating material depend on both the volatile content and the mass eruption rate [8]. For this reason, as the gas amount within the erupted gas-magma mixture increases, the probability of formation of pond-fed flows quickly decreases, and both gases and magma fragments are expected to be transported and deposited after a longer flight time within the erupting plume. Volcanic materials will land already solid, thus generating the observed patterns of diffuse pyroclastic deposits.

Since the Voyager era, a remarkable variability in the volcanic activity has been observed at most volcanic centers [13]. We explain the likely frequent changes of volcanic styles, even for the same volcanic center, as mainly due to the fact that even a very low volatile amount within the magma can cause gentle flow-like activity to turn into explosive plume activity. Furthermore, the expected non-uniform distribution of volatile deposits within the upper crust and on the Ionian surface make these changes still more likely to occur. In support of this, near most volcanic centers, plume fallout deposits often appear to be associated with flow-like deposits. At Pillan Patera, a new dark flow-like feature up to 75 km long has been seen near the center of the "fresh" dark fallout [5]. At Prometheus, a lava flow has formed contemporaneously with the detected plume activity. At Maui, only flow-like activity was seen in the Galileo era, but during the Voyager era Maui was the site of an eruptive plume [13]. A similar phenomenon can be observed near other important volcanic centers, like Volund, Loki, etc. The total disappearance of plume activity could also be explained by the supply of crustal volatiles in the vicinity of the volcanic conduit being terminated; this could be due to long-term continuous activity which would exhaust the local supply of volatiles before any kind of replenishment could occur.

REFERENCES: [1] Lopes-Gautier et al. (1997) Geophys. Res. Lett., 24, 20, pp. 2439-2442; [2] McEwen et al. (1997) Geophys. Res. Lett., 24, 20, pp. 2443-2446; [3] McEwen et al. (1998a) Science, 281, pp. 87-90; [4] Geissler et al. (1997) In "Io during the Galileo era", p. 40, Lowell Observatory, Flagstaff, AZ; [5] McEwen et al. (1998b) Icarus, 135, pp. 181-219; [6] Carlson et al. (1997) Geophys. Res. Lett., 24, 20, pp. 2479-2482; [7] Stansberry et al. (1997) Geophys. Res. Lett., 24, 20, pp. 2455-2458; [8] Wilson and Head (1981) J.Geophys. Res., 86, B4, 2971-3001; [9] Wilhelms (1987) U. S. Geological Survey Prof. Paper, 1348; [10] Davies (1988) Ph.D. thesis, University of Lancaster, Lancaster, U.K.; [11] Davies (1996) Icarus, 124, pp. 45-61; [12] Head and Wilson (1989) J. Volcanol. Geotherm. Res., 37, pp. 261-271; [13] Strom and Schneider (1982) In "Satellites of Jupiter", pp. 598-633.